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A NEW HYBRID APPROACH FOR LEGAL AMOUNT RECOGNITION

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This paper presents a new hybrid approach for legal amount recognition on Italian bankchecks. It exploits the consideration that a legal amount can be described as a sequence of 'core' groups of words separated by suitable 'separator' words. Therefore, an analytical strategy is used to perform amount segmentation into 'core' groups of words that are then recognized according to a global approach. For this purpose, lexical and syntactical a-priori knowledge of the domain of application is used both for amount segmentation and recognition. The experimental results demonstrate the effectiveness of the new approach.

1 Introduction

Millions of bank-checks issued from thousands of banks and financial institutions are daily used all over the world for monetary transactions. Bank-checks are very complex documents which contains pictorial images (colored layout), many pre-printed components of different types (logos, guidelines, labels of data-entry field, etc.), and several data-entry fields that must be filled by the users (legal and courtesy amounts, payee, issuing place and data, etc.). Therefore, bank-check processing generally requires the integration of several software components, each one devoted to a specific processing task: layout analysis, pre-printed component removal, data field identification, extraction of filled components, recognition of user-entry data, signature verification and so on. Therefore, bank-check processing is rightly considered an important research field both for the economic and scientific point of view which attracts many research groups [1].

One of the most complex task in bank-check processing is the legal amount recognition. In fact, it concerns with different ways of writing, changeable from person to person, and dependently from physical and physiological conditions of the writers [2]. For this purpose, all the contextual knowledge available is used and several complementary approaches are generally combined to achieve high reliable results in legal amount recognition. Dimauro and oth. [3] use the courtesy amount to obtain a set of segmentation hypotheses for the legal amount and three different algorithms for word recognition are combined: fully-analytical, mixed and fully-global. Finally, the lists of candidate words, obtained by the three algorithms, are merged, in order to obtain a list of high-confidence candidates. In Simon and oth. [4], segmentation is performed in five successive steps for connected component detection, skeletonization of the components, detection of candidate points for segmentation, identification of graphemes and ligatures, and extraction of

potential character images based on a single grapheme or on groups of two, three or four graphemes. Successively, word candidates are identified using suitable distances between adjacent graphemes based on the minimum run-length between the vertical segments of the two adjacent graphemes. Character recognition is performed by combining three algorithms: a Bayes classifier, a Template-based classifier, and a Neural Network Classifier. Two algorithms are used for word recognition. The first uses an analytical approach, the second uses a holistic approach. In the paper of Leroux and oth. [5], a left-to-right Hidden Markov Models (HMM) is used to represent each word class. A combined system based on HMM and Markov Random Fields (MRF) is also adopted by Saon and oth. [6]. Filatov and oth. [7] use dynamic programming for legal amount recognition and the Levenshtein distance. A combination of symbolic analyser and a neural analyzer is used for legal amount recognition by Dodel and others [8]. The symbolic analyzer is specifically designed for ascending and descending patterns, while neural analyzer is used for the body of the legal amount. Chiang proposes a model for handwritten word recognition based on hybrid neural network [9]. An indexing scheme is proposed by Han and oth. [10] based on the string hashing version of a local associative indexing technique. In this case a nearest neighbor classifier is used for word matching.

In this paper a new hybrid approach is presented for legal amount recognition on Italian bank-checks. It uses an analytical technique to segment the amount in a sequence of 'core' groups of words, and a global technique to recognize each 'core' groups of words. In the recognition process of the legal amount, both lexical and syntactical knowledge are used.

2 Italian Bank-checks: the Document Structure

Notwithstanding all bank-checks contain similar information, the format of a bank-check changes from country to country and therefore specific solutions must be considered for each country depending on the particular characteristics.

An Italian bank-check consists of many textual components and data-entry fields [3]. The most important textual components are the identification code of the bank and of the bank-agency, which are preprinted on the lower part of the check using a magnetic ink CMC-7 code. The most important user-entered information fields are the signature, the courtesy (digit) amount, and the legal (worded) amount which is written as a single word obtained by joining several basic words. In this sense, the recognition of Italian legal amounts is more difficult than the recognition of legal amounts on bank-checks of other countries (French, US, UK, etc.) that are written as well-separate sequences of basic words. Other data-entry fields regard the place and date of issuing and the payee.

Generally, in a processing system for Italian bank-checks [3], the numeric string containing the bank identification code, the bank-agency identification code, the check number and the customer's account number is processed at first. Since the string on the bank-check is in a fixed position it can be easily extracted and recognized. The bank identification code and the bank-agency identification code are used to retrieve, from the bank-reference database, the position of the user-entered fields for courtesy and legal amounts and for the signature. The check number is used to retrieve from the customer

reference database the personal information about the customer's signatures for bank-check authentication by signature verification.

3 Contextual Knowledge for Italian bank-check Recognition

The use of contextual knowledge in handwritten word recognition has been massively investigated in recent years [10,11]. In bank-check processing, lexical and syntactical information have been used [3,4], as well as information obtained from other agents (bank-code and bank-agency-code for layout analysis, account number for signature verification, courtesy amounts for legal amount recognition etc.) [5,6,7]. In this paper only lexical and syntactical knowledge are used [12]:

- The lexical knowledge consists of the lexicon of the basic words that are used to form any Italian worded amount. They are: *uno, due, tre, quattro, cinque, sei, sette, otto, nove, dieci, undici, dodici, tredici, quattordici, quindici, sedici, diciassette, diciotto, diciannove, venti, ventuno, ventotto, trenta, trentuno, trentotto, quaranta, quarantuno, quarantotto, cinquanta, cinquantuno, cinquantotto, sessanta, sessantuno, sessantotto, settanta, settantuno, settantotto, ottanta, ottantuno, ottantotto, novanta, novantuno, novantotto, cento, mille, mila, unmilione, milioni*.

- The syntactic knowledge consists of the following syntactic rules used to combine basic words in an Italian amount (legal amount less than 999,999,999 Italian Lire):

```

<BANK-CHECK_AMOUNT>::=
<MILLION_AMOUNT> + <THOUSAND_AMOUNT> + <HUNDRED_AMOUNT> /
<MILLION_AMOUNT> + <THOUSAND_AMOUNT> /
<MILLION_AMOUNT> + <HUNDRED_AMOUNT> / <MILLION_AMOUNT> /
<THOUSAND_AMOUNT> + <HUNDRED_AMOUNT> /
<THOUSAND_AMOUNT> / <HUNDRED_AMOUNT>
<MILLION_AMOUNT>::=<COMPOSED_AMOUNT> + milioni / unmilione
<THOUSAND_AMOUNT>::=<COMPOSED_AMOUNT> + mila / mille
<HUNDRED_AMOUNT>::=<COMPOSED_AMOUNT> / uno
<COMPOSED_AMOUNT>::=<SIMPLE_THREE_DIGIT_AMOUNT> /
<SIMPLE_THREE_DIGIT_AMOUNT> + <TWO_DIGIT_AMOUNT> /
<SIMPLE_THREE_DIGIT_AMOUNT>+ <SIMPLE_TWO_DIGIT_AMOUNT> /
<SIMPLE_THREE_DIGIT_AMOUNT>+<SIMPLE_TWO_DIGIT_AMOUNT>
+<ONE_DIGIT_AMOUNT> /
<SIMPLE_THREE_DIGIT_AMOUNT> + <ONE_DIGIT_AMOUNT> /
<SIMPLE_TWO_DIGIT_AMOUNT> /
<SIMPLE_TWO_DIGIT_AMOUNT> + <ONE_DIGIT_AMOUNT> /
<ONE_DIGIT_AMOUNT> /
<TWO_DIGIT_AMOUNT>
<SIMPLE_THREE_DIGIT_AMOUNT>::=<ONE_DIGIT_AMOUNT>+<cento /cento

```

<SIMPLE_TWO_DIGIT_AMOUNT>::= venti / trenta / quaranta / cinquanta / sessanta / settanta / ottanta / novanta
 <TWO_DIGIT_AMOUNT>::= dieci / undici / dodici / tredici / quattordici / quindici / sedici / diciassette / diciotto / diciannove / ventuno / ventotto / trentuno / trentotto / quarantuno / quarantotto / cinquantuno / cinquantotto / sessantuno / sessantotto / settantuno / settantotto / ottantuno / ottantotto / novantuno / novantotto.
 <ONE_DIGIT_AMOUNT>::= due / tre / quattro / cinque / sei / sette / otto / nove.

The approach proposed in this paper starts from the consideration that an Italian legal amount, which is written as a single word joining several basic words, can be considered as a sequence of 'core' groups of words connected by means of 'separator' words. A 'core' group of basic words is a <COMPOSED_AMOUNT> that identifies a three digit number (from 1 to 999). A 'separator' word is a basic word that can divide 'core' groups of basic words. In our case the basic words are "mille", "mila", "unmilione", "milioni".

4 Singular Patterns for Handwritten Word Recognition

Singular patterns have long been considered as robust features for handwriting recognition [13,14]. In this paper, singular patterns are used: (1) for segmenting the legal amount into 'core' groups of words, (2) for recognizing the 'core' groups of words. Singularities are the ascending and descending patterns of the words, which are positioned outside the region of the body of the word, delimited by the Lower Basic Line and Upper Basic Line. For the lexicon of basic words of Italian legal amount the set of singularities corresponds to characters: "d", "l", "q", "t".

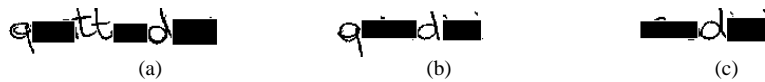


Figure 1: Singular Patterns

It is easy to verify that the sequence of singularities conveys powerful information in word recognition. For example, in figure 1 three basic words belonging to the lexicon of basic words of Italian amounts are shown. Notwithstanding the body of the word is not visible, from the analysis of the sequence of the singularities we can recognize the words (a) "quattordici", (b) "quindici", (c) "undici" o "sedici". According to this consideration, we define *class by singularities* the set of the words of dictionary that have the same sequence of singularity. For example, the words "ventotto" and "sessantotto" have the same sequence of singularities ("ttt") and therefore belong to the same class (Class "ttt").

5 A New Technique for Italian Bank-check Recognition

The technique proposed for word recognition is based on the following phases:

1. Amount description by a graph-based model;
2. Detection of singular patterns for the segmentation of legal amounts into 'core' groups of basic words;
3. Identification of Candidate 'core' groups of basic words.

5.1 Amount description by a graph-based model

The aim of this phase is to achieve a graph-based representation of the legal amount [15]. In the graph representation, arcs denote hand-written segments of the amount while nodes correspond to *cross regions*, *bend regions* and *end regions* in the amount image. For this purpose, the word image is scanned four times using different scanning directions (horizontally, vertically, -45° , $+45^\circ$) in order to extract oriented segments (see [15,16] for details). Successively, the four images are superimposed (Figure. 2a) and the parts which are not included into segments are first thinned [17] and then classified as *cross region*, *bend region* or *end region*. In such a way a graph-based representation of the word image is completed which conveys basic information on the word shape without retaining useless details (Figure. 2b).

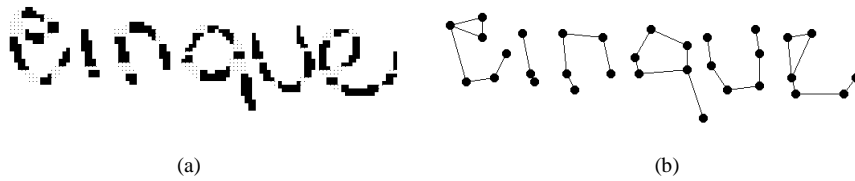


Figure 2: Graph representation of the basic word "cinque"

5.2 Detection of Singular Pattern for legal amounts segmentation

The graph-based representation of the word image is coded by finding typical structures in the graph: line_segment, ascenders, descenders, loops, concavities, convexities. For this purpose, upper and lower basic lines are considered in order to identify upper and lower regions of the word image. Directional information of the structures are also considered (horizontal, vertical, $+45^\circ$, -45°).

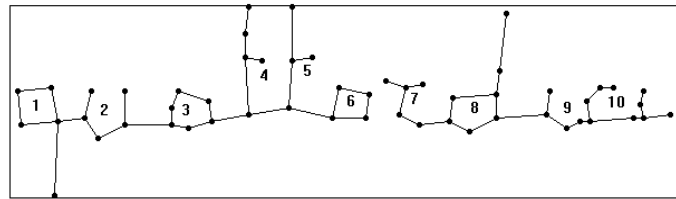


Figure 3: Structure extraction for the basic word "quattordici"

In the graph of Figure 3 the following structures are recognized: (1) loop and descender (vertical), (2) concavity (vertical), (3) loop, (4) ascender (vertical), (5) ascender (vertical), (6) loop, (7) concavity (vertical) - concavity (+45°), (8) loop - ascender (vertical), (9) concavity (vertical), (10) concavity (horizontal). Successively, some typical structures are detected in order to infer information about the presence of singular patterns as reported in Table 1.

Table 1: Identification of Singular Patterns

Structure	Candidate Singularity
Descender + loop	"q"
Ascender + loop (in the middle region)	"d"
Ascender + loop (in the upper region)	"l"
Ascender + intersection (in the upper region)	"t"

In such a way the amount image is finally coded as a sequence of basic symbols (C_1, C_2, \dots, C_n) where $C_i \equiv (C_{i_type}, C_{i_orientation})$ and $C_{i_type} \in \{\text{line_segment, ascenders, descenders, loops, concavities, convexities, "q", "d", "l", "t"}\}$, $C_{i_orientation} \in \{\text{horizontal, vertical, +45°}, -45°\}$

Table 2: Legal Amount: categories

▪ Category 1- Singularities: "l" - "l"	
Sub Cat. 1.1) CBW - milioni - CBW - mila - CBW	
Sub Cat. 1.2) CBW - milioni - CBW - mila	
Sub Cat. 1.3) unmilione - CBW - mila - CBW	
Sub Cat. 1.4) unmilione - CBW - mila - CBW	
▪ Category 2- Singularities: "l" - "ll"	
Sub Cat. 2.1) CBW - milioni -	mille - CBW
Sub Cat. 2.2) CBW - milioni -	mille
Sub Cat. 2.3) unmilione -	mille - CBW
Sub Cat. 2.4) unmilioni -	mille
▪ Category 3- Singularities: "l"	
Sub Cat. 3.1)	CBW - mila - CBW
Sub Cat. 3.2)	CBW - mila
▪ Category 4- Singularities: "ll"	
Sub Cat. 4.1)	mille - CBW
Sub Cat. 4.2)	mille

The singular patterns allow a robust decomposition of the legal amount into 'core' groups of basic words (CBW). Precisely, from the consideration that only the 'separator' words (mille, mila, unimilione, milioni) contains the singularity "l" and no other basic word, the detection of a singular pattern "l" or "ll" is used to identify the position of the 'separator' words (if exists) in the legal amount that are then recognized by means of the analysis of the code symbols close to the "l". The net result of this approach is that it makes possible to select the

category and sub-category which the legal amount belongs to as Table 1 shows. Successively, the codes of the 'core' groups of basic words are isolated by subtracting the codes of the 'separator' words from the code of the legal amount.

5.3 Identification of Candidate 'core' groups of basic words

After the code of a CBW is extracted, then its recognition is possible. The recognition of a CBW is performed by matching its code against the codes of a suitable set of prototypes. For this purpose several prototypes are realized by concatenating the codes of those basic words whose sequence of singularities is consistent to the sequence of singularities of the CBW, which are syntactically checked. In such a way only a reduced set of prototypes are considered for the matching. For example if we consider the CBW "quattrocento", the sequence of singularities is: "q" - "tt" - "t". The prototypes that must be realized are those reported in Table 3.

Table 3: Prototypes of 'core' groups of basic words (sequence of singularities: "qttr")

Class Sequence	basic words	'core' groups of words (syntax checked)
Class (qtt)	quattro	quattrocento
Class (t)	cento	
Class (q)	cinque	---
Class (tt)	sette, otto, trenta, trentuno	
Class (t)	tre, venti, ventuno, sessanta sessantuno, novanta, novantuno, cento	
Class (qt)	quaranta, quarantuno, cinquanta, cinquantuno	quarantasette, quarantotto, ciquantasette, cinquantotto
Class (tt)	sette, otto, trenta, trentuno	

After the set of prototypes has been defined, they are matched against the code of the CBW. A dynamic programming technique is used for this purpose [15,18]. Let be $C = (C_1, C_2, \dots, C_n)$ the code of the CBW and $P = (P_1, P_2, \dots, P_m)$ the code of a prototype, an elastic matching is used to obtain the quantity D^* defined as:

$$\min_w D(C, P) = \sum_{k=1}^K d(w_k)$$

where:

- $W = (w_1, w_2, \dots, w_K)$ is a sequence of couples of indexes (i.e. $w_k = (i_k, j_k)$) which satisfies the *Monotonicity*, *Continuity* and *Boundary Condition*;
- $d(w_k)$ is a distance measure between the samples of C and P (i.e. $d(w_k) = d(C_{i_k}, P_{j_k})$).

The 'core' group of basic words is then classified according to the prototype for which the value D^* is minimum. The distance measure used for matching two symbols x and y in codes C and P has been derived according to some heuristics:

Case 1) x_type and y_type is the same:

$$\begin{aligned} d(x, y) &= 0 && \text{if } x_orientation \text{ and } y_orientation \text{ are equal} \\ d(x, y) &= a && \text{if } x_orientation \text{ and } y_orientation \text{ differ of } 45^\circ \text{ or less} \\ d(x, y) &= 2a && \text{if } x_orientation \text{ and } y_orientation \text{ differ of more than } 45^\circ \end{aligned}$$

Case 2) x_type and y_type is different:

$$d(x, y) = b.$$

where the values a and b have been derived by an iterative procedure based on the analysis of intra-class and inter-class distances of the prototypes of basic words available in the reference database [15].

6 Experimental Results

The system has been tested using a reference database (RD) of 513 basic words written by different writers. For each basic word, from 4 to 7 specimens are included in RD. The test database (TD) consists on 1083 legal amounts extracted from Italian bank-checks which have a number of basic words ranging from 2 to 10.

In Figure 4 a specimen of the TD corresponding to the Italian amount "*sedicimilaottocento*" is reported (a) after the determination of the Lower and Upper Basic Lines, (b) after slant correction, (c) after segmentation. In this case the sequence of singularities is "d" - "l" - "tt" and "t". The amount belongs to category 3.1 (see Table 2) and it is segmented as "*sedici*" (CBW) - "*mila*" ('separator' word) - "*ottocento*" (CBW).

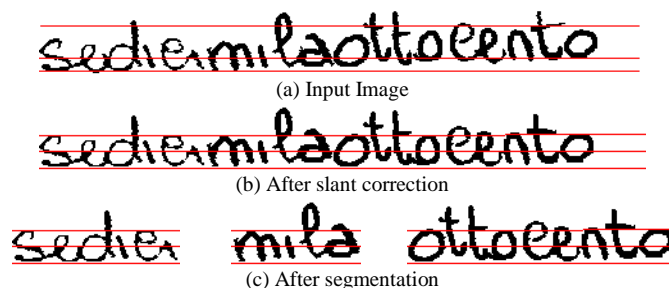


Figure 4: A Legal Amount

Table 4 reports the experimental results which demonstrate the effectiveness of the new approach compared to other approaches in literature [3-10]: the recognition rate for the

entire test database is 44% for the first position while , 26% for positions from 2 to 10 and 15% for positions greater than 10. Rejection is 13% and it is mainly due to uncorrected segmentation.

Table 4: Recognition results

Number of Basic Words in the amount	Number of specimens	Position		
		1	2-10	>10
2	12	83%	14%	3%
3	54	63%	25%	6%
4	176	57%	31%	8%
5	140	62%	27%	9%
6	156	48%	25%	13%
7	185	34%	37%	17%
8	256	35%	31%	16%
9	79	35%	28%	19%
10	25	31%	25%	23%

7 Conclusion

This paper presents a system for legal amount recognition of Italian bank-checks. An advanced processing scheme is used since an Italian legal amount is written as a unique word and it can be very complex. It is based on the observation that singular patterns provide information useful both for segmenting the legal amount into 'core' groups of basic words and for recognizing each group. The recognition process also uses lexical and syntactic knowledge in order to achieve higher performance.

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